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NACA

RESEARCH MEMORANDUM

for the

Bureau of Aeronautics, Department of the Navy

EFFECT OF ANGLE OF INCIDENCE OF SECOND-STAGE VANE ASSEMBLY ON THIRD-STAGE COMPRESSOR-BLADE VIBRATION AND ENGINE PERFORMANCE

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WASHINGTON

JUNE 12 1951

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SUMMARY

Strain-gages were used to measure blade vibrations causing failures in the third stage of a production 11-stage axial-flow compressor. After the serious third-stage vibration was detected, a series of investigations were conducted with second-stage vane assemblies of varying angles of incidence. Curves presented herein show the effect of varying the angle of incidence of second-stage vane assembly on third-stage rotor-blade vibration amplitude and engine performance. A minimum vibration amplitude was obtained without greatly affecting the engine performance with a second-stage vane assembly of 9° greater angle of incidence than the assembly normally furnished with the engine.

INTRODUCTION

Several blade failures in production J34 11-stage axial-flow compressors have been reported by the manufacturer. The failures were primarily in the third rotor stage and usually occurred at a speed slightly below the normal cruising speed. Some failures occurred after a few hours of operation, whereas others after long periods of operation. A series of vibration surveys is being conducted at the NACA Lewis laboratory to determine the cause of blade failures and to devise a means of eliminating them.

The investigation consisted of instrumenting the compressor rotor blading with resistance-wire strain gages and operating the complete engine under normal conditions. After a critical third-stage vibration was detected, a systematic investigation was conducted to determine its source and to find means of correcting the condition.

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Data showing the effect of changing the angle of incidence of the blading in the second-stage stator-vane assembly on third-stage rotor-blade vibration amplitude and engine performance are presented herein.

APPARATUS AND PROCEDURE

A J34 jet-propulsion engine was operated in a sea-level-type test stand for this investigation. Commercial resistance-wire strain gages were mounted on the rotating compressor blades, and the lead wires were brought through drilled passages in the compressor to a 19-ring slip-ring assembly as described in references 1 to 3. A 12-channel recording oscillograph was used to record the strain-gage signals. The strain-gage installation included two instrumentated blades on all stages except the first, second, and third which had three, three, and seven, respectively.

After the third-stage vibration had been detected, a series of tests followed which included the testing of a series of second-stage stator-vane assemblies (fig. 1) with various angles of incidence. The assemblies tested included 6° open, 0° (standard), 3° closed, 6° closed, 9° closed, and 12° closed. The standard vane is the vane assembly normally furnished with the engine, and the closed angle indicates a vane with higher angle or incidence.

All vane assemblies were fabricated by the engine manufacturer and sent to the NACA for evaluation. To prove that the vibrations were not a peculiarity of the vanes provided with the engine, a second set of standard vanes was installed and similar high amplitude vibrations were measured. Then the vanes with other incidence angles were investigated.

Data were recorded to calculate the effect of these vane assemblies on the serious third-stage vibration and engine performance.

RESULTS AND DISCUSSION

The strain-gage data from the third-stage rotor blades substantiated that failures reported in the J34 compressor were caused by first bending mode vibration. The speed at which failures have been known to occur, 9300 rpm, correlated with the speed where unusual high amplitude vibration signals were observed. On occasions when the engine was operated in an altitude test stand, strain-gage signals indicated the presence of vibratory stresses of $\pm 42,000$ pounds per square inch, which is sufficient to cause failure if this condition were allowed to persist. An involved series of tests and changes was made to gain general knowledge, but only the engine modifications resulting in reduction of blade vibrations are presented herein.

Through conferences between representatives of the engine manufacturer and the NACA, the decision was made to investigate the effect of the angle of incidence of the stator vanes immediately preceding the third rotor stage of the compressor. The results of such an investigation conducted in a sea-level test stand are shown in figure 2. The vibratory stress levels noted on this plot are averages of numerous data points of the maximum amplitude obtainable in the critical speed range for each stator angle. The number of stator assemblies tested for each angle, the resulting average stress, and the percentage of the stress produced by the standard vanes are presented in the following table:

Angle of incidence	Vane assemblies investigated	Average vibratory stress in third-stage blades (lb/sq in.)	Percentage of standard stress
6° open	3	$\pm 10,700$	62.0
0° (standard)	2	$\pm 17,250$	100.0
3° closed	1	$\pm$ 8,350	48.4
6° closed	5	$\pm$ 4,550	26.4
9° closed	1	$\pm$ 1,600	9.3
12° closed	3	$\pm$ 2,400	13.9

A change of 3° closed reduced the vibratory stress to less than half and would possibly bring the vibration below the danger point. A change, however, to 9° greater incidence would assuredly eliminate all third-stage vibration failures of this compressor design in the critical speed range.

The complete speed range (to 12,500 rpm) was investigated with vanes of each angle from the vibration standpoint as well as to determine engine performance. No new vibration of significant amplitude was introduced by any of the new angles. The effects on over-all engine performance is illustrated in figures 3 and 4. Although a total change of 18° (6° open to 12° closed) was investigated, very little or relatively no change in engine performance was detected.

SUMMARY OF RESULTS

From the analysis of oscillograph records and engine data, the following results were obtained:

1. The 9° closed vane assembly produced the lowest vibration amplitude of the third-stage rotor blades.

2. A change of 18° in the second-stage vane assembly had little or no effect on the over-all engine performance.

3. The 9° closed vane assembly presented the most satisfactory over-all engine performance.

Lewis Flight Propulsion Laboratory,
National Advisory Committee for Aeronautics,
Cleveland, Ohio, May 31, 1951.

REFERENCES

1. Meyer, André J., Jr., and Calvert, Howard F.: Vibration Survey of Blades in 10-Stage Axial-Flow Compressor. II - Dynamic Investigation. NACA RM E8J22a, 1949.

2. Meyer, André J., Jr., and Calvert, Howard F.: Vibration Survey of Blades in 10-Stage Axial-Flow Compressor. III - Preliminary Engine Investigation. NACA RM E8J22b, 1949.

3. Meyer, André J., Jr., Calvert, Howard F., and Morse, C. Robert: Effects of Obstructions in Compressor Inlet on Blade Vibration in 10-Stage Axial-Flow Compressor. NACA RM E9L05, 1950.

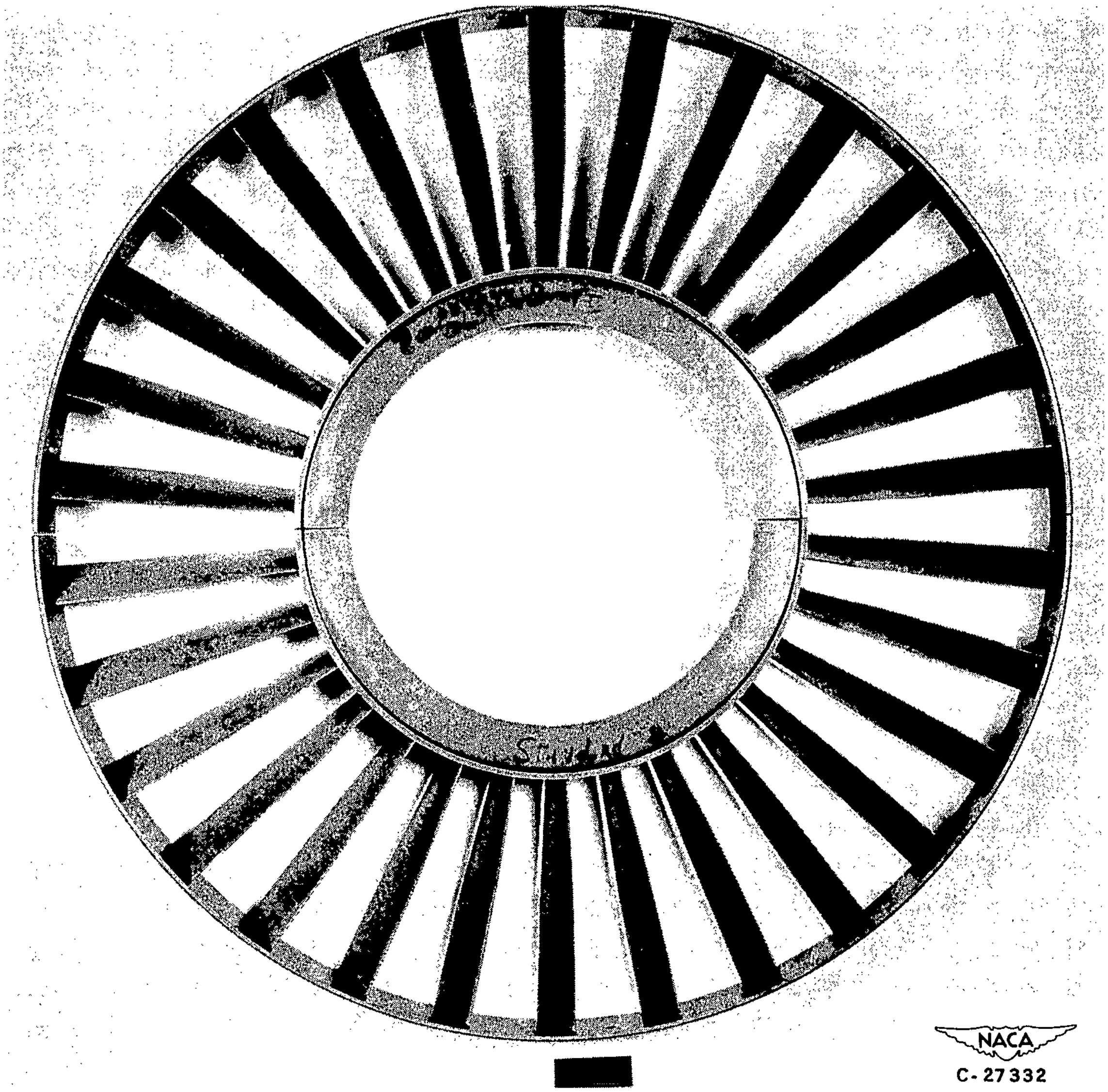


Figure 1. - Second-stage vane assembly.

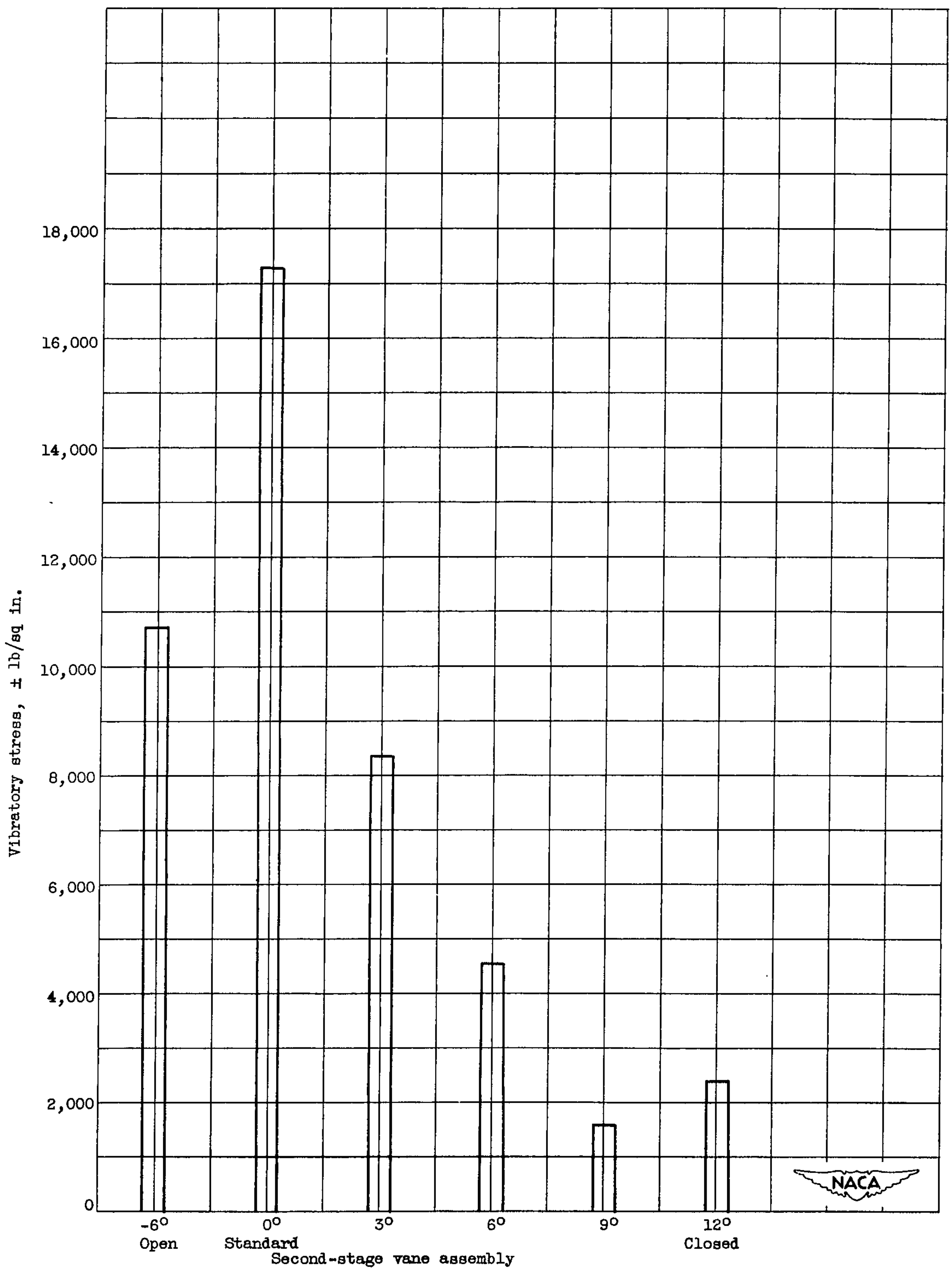
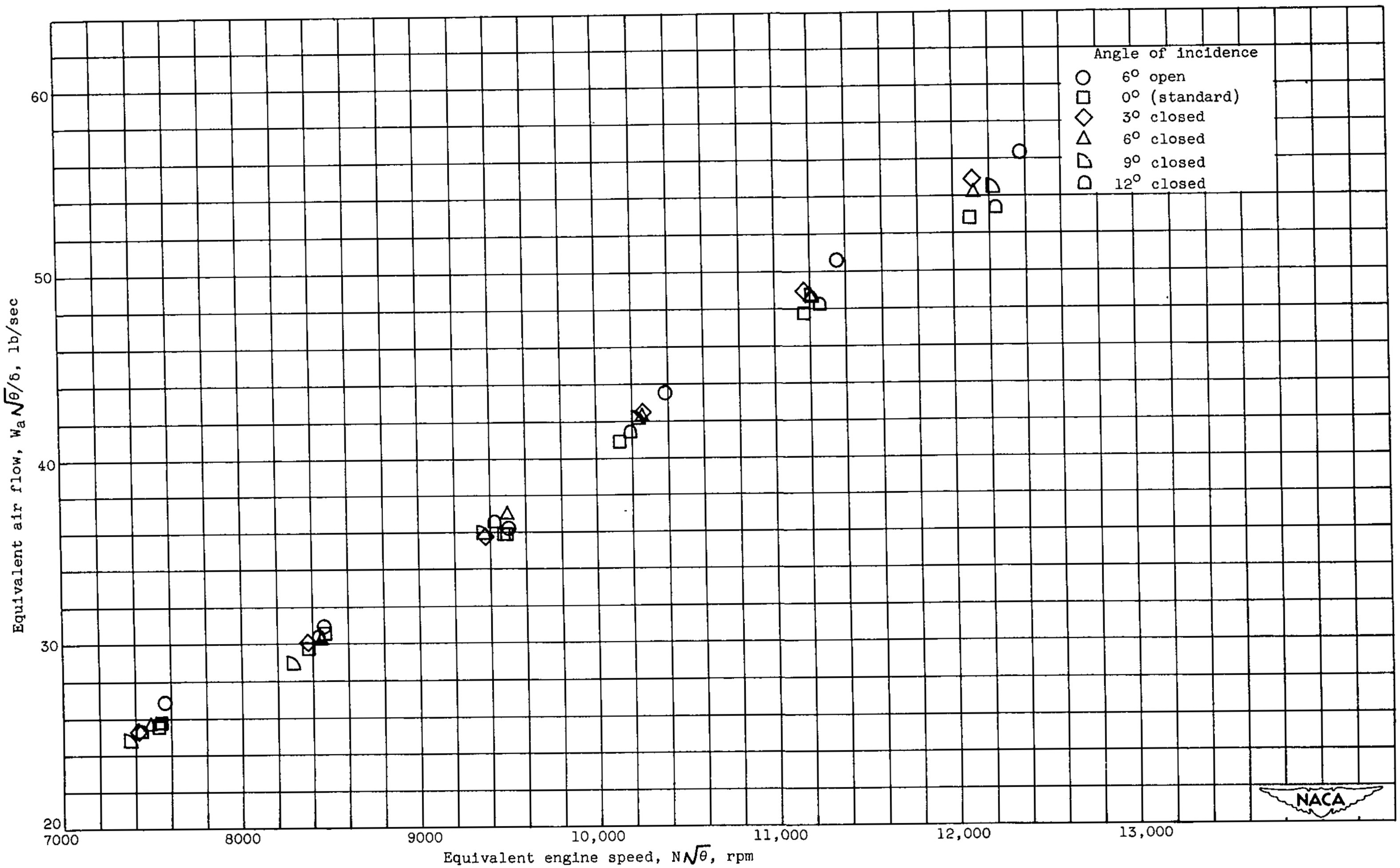
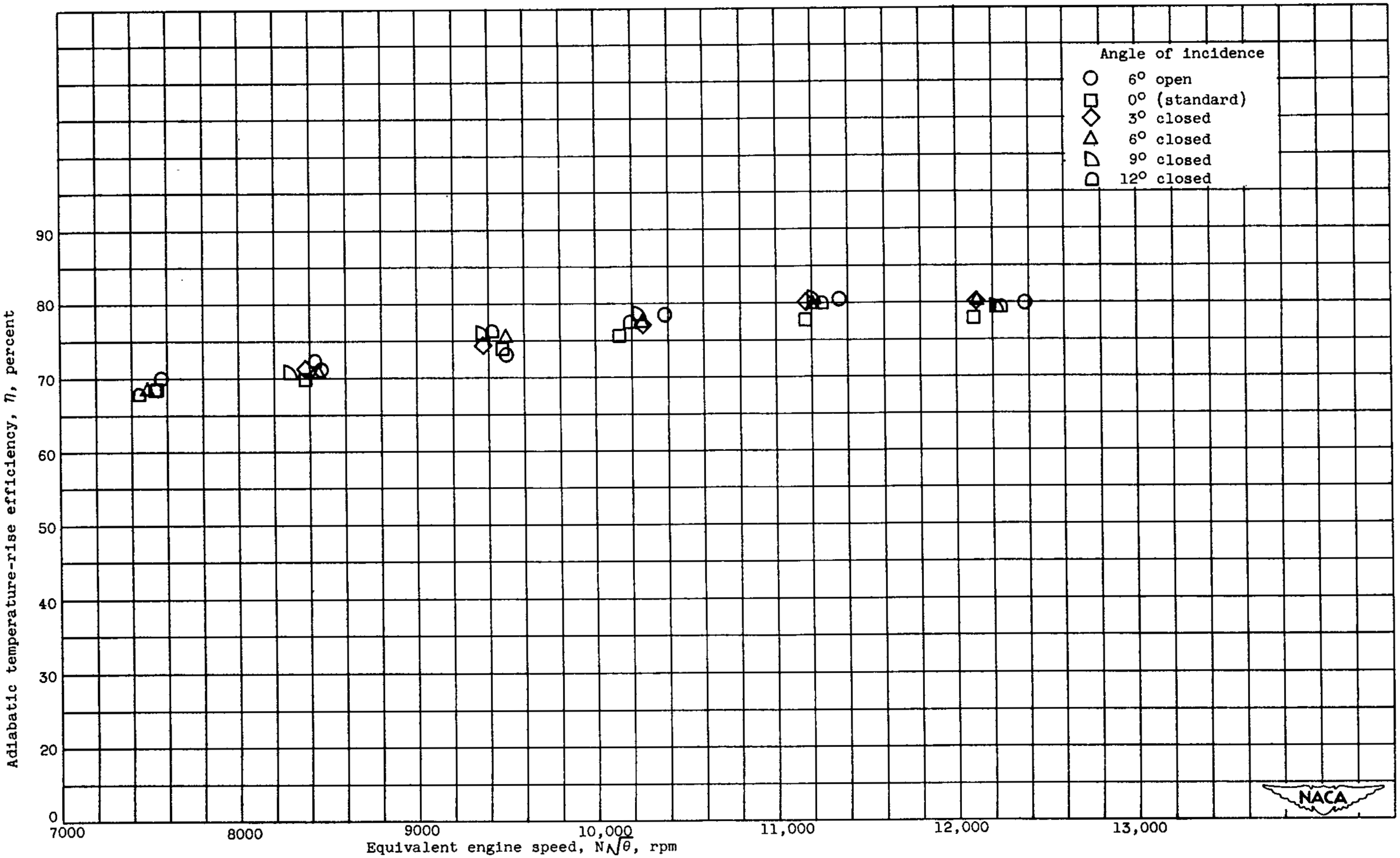


Figure 2. - Effect of second-stage vane-assembly angle of incidence on third-stage vibration.



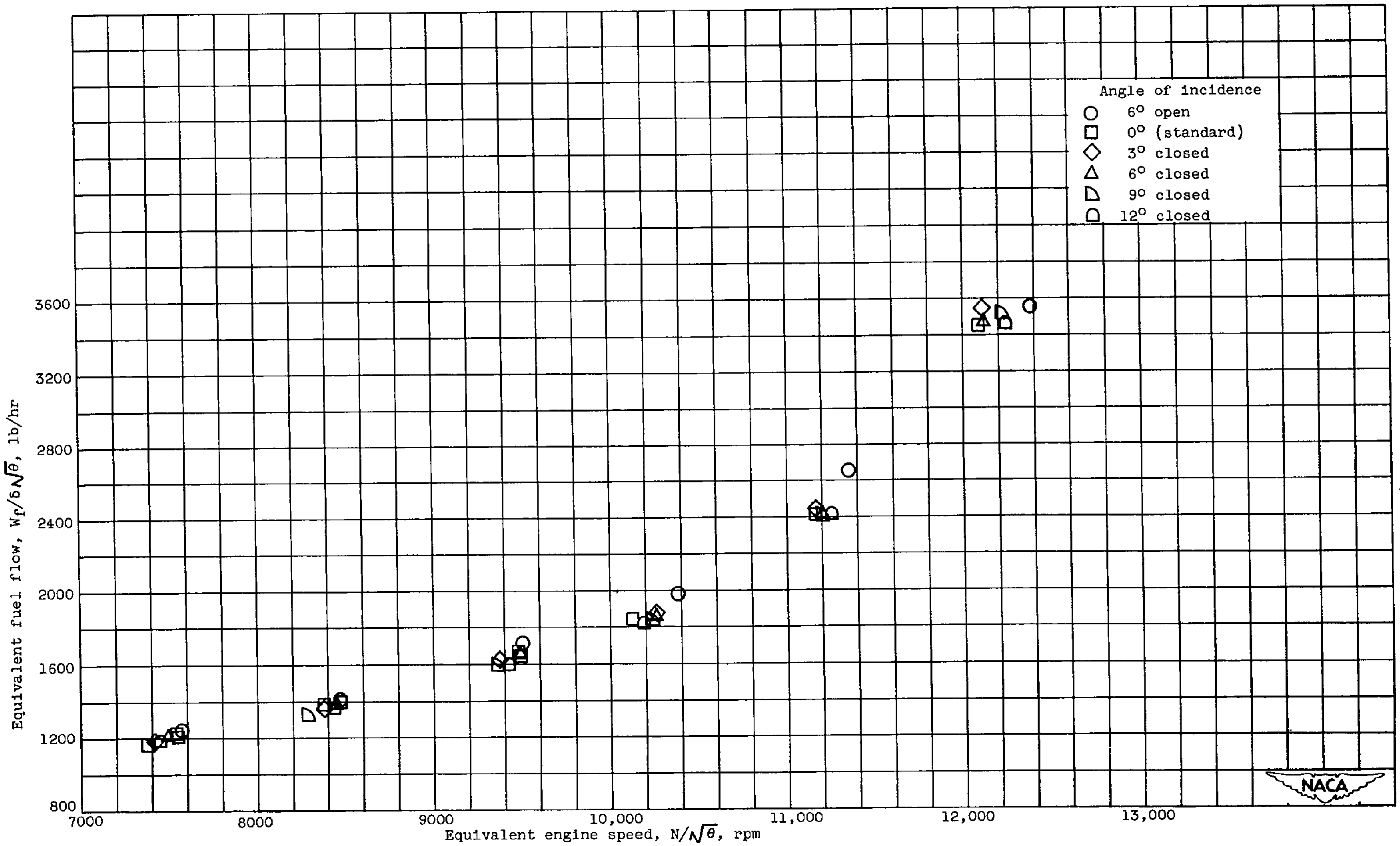
(a) Equivalent air flow.

Figure 3. - Performance characteristics of J34 compressor with various second-stage vane-assembly angles of incidence.



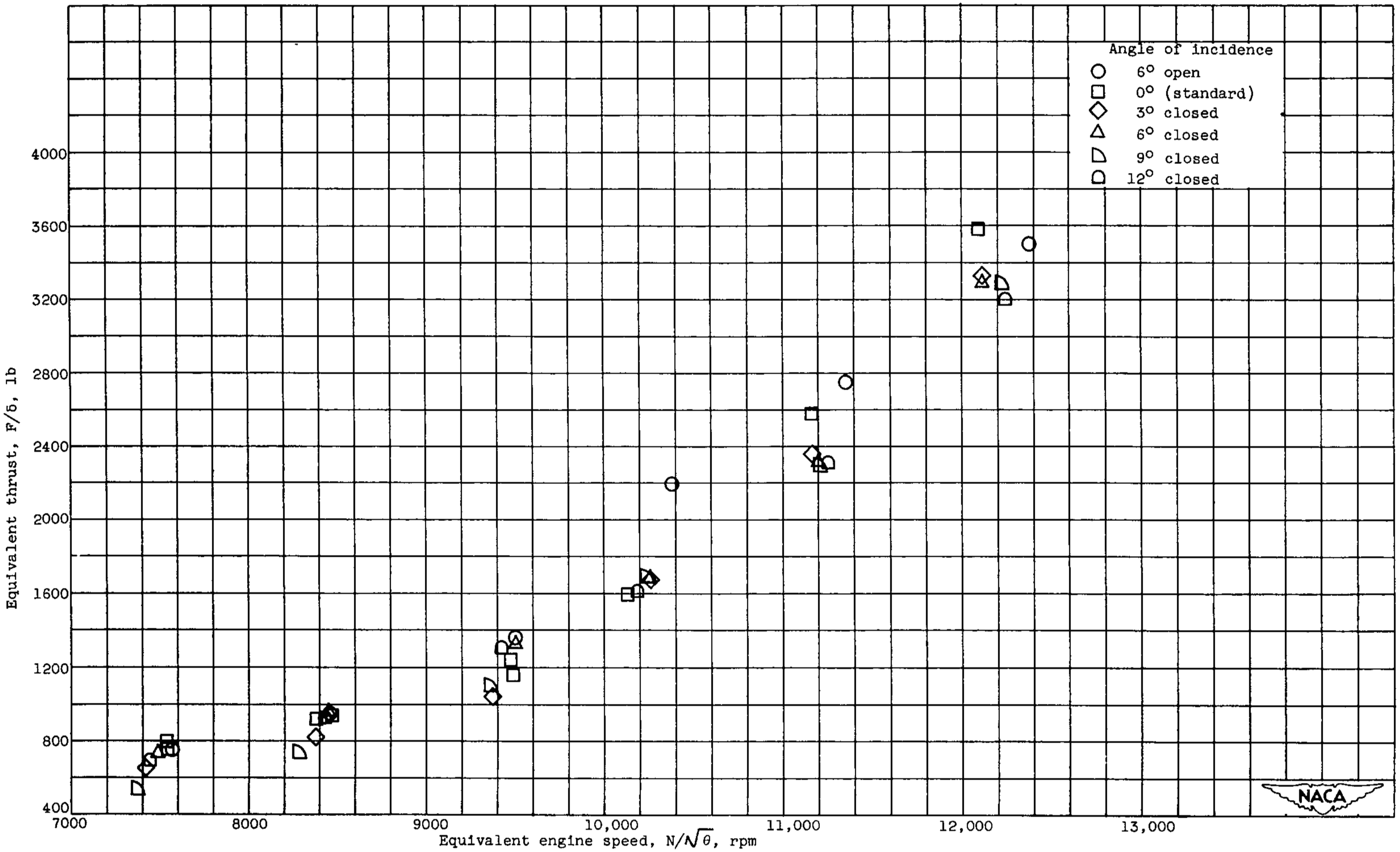
(b) Adiabatic temperature-rise efficiency.

Figure 3. - Concluded. Performance characteristics of J34 compressor with various second-stage vane-assembly angles of incidence.



(a) Equivalent fuel flow.

Figure 4. - Performance characteristics of J34 engine with various second-stage vane-assembly angles of incidence.



(b) Equivalent thrust.

Figure 4. - Concluded. Performance characteristics of J34 engine with various second-stage vane-assembly angles of incidence.

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